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FOREWORD

We consider it a privilege to provide, for the schoolmen and women of Kansas, a summary report of the first conference held at The University of Kansas on programmed learning.

Now that programmed materials have reached a stage of development which will permit them to circulate beyond the experimental situation and into the public school classroom, we think it is important not only to call attention to the existence of these materials but also to begin an evaluation of their usefulness. Certainly we must consider whether programmed learning can help us to teach the boys and girls of Kansas more effectively.

To those who attended the conference this summary report will serve as a review; to those who did not, it will enable them to participate in the conference vicariously.

THE EDITOR

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An Introduction to the Conference

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On April 15 of this year the Bureau of Educational Research, the School of Education, and University Extension hosted a conference on programmed learning materials on the University of Kansas campus. The timeliness of this conference was emphasized by the attendance of some two hundred educators, and the pervasiveness of interest in the topic was reflected in the number of disciplines and academic levels of instruction represented by those in attendance.

It was recognized that many educators who are interested in this topic had not been able to attend the conference, and it was felt that many interested educators, whether they had attended the conference or not, would welcome a printed summary of the conference proceedings. This report is intended to be a service to those educators who desire information about and opinions on programmed materials.

The concept of programmed or self-instructional materials is not new to the literature of education. The first recognized report of such materials dates back at least to the 1920's and reference to such teaching aids appeared occasionally in articles during the next thirty years. Only recently, however, has the concept received widespread attention, and still today the number and variety of self-tutoring materials commercially available is severely limited.

That programmed materials will soon be available in quantity for schools is reflected in the efforts of many publishing houses. In addition, some companies have advertised their product in daily newspapers, and these announcements have been directed to the parent who wishes only the best education for his children and to the adult who wishes to improve himself.

There is enough evidence available to suggest that programmed materials are not a fad; there is evidence available to suggest that programmed materials will find a useful and accepted place in public education; there is also evidence available to suggest that many questions regarding programmed materials remain unanswered. The differences in opinion over lecture versus discussion methods are small indeed compared to differences in opinion over some aspects of programmed materials.

Professional educators have the responsibility of evaluating any process or technique that may increase the efficiency of the teaching process. These evaluations must be based on relevant and complete information—information ranging from the underlying theory to empirical research findings. In recent months, the interested public has frequently called upon professional

educators for opinions on programmed learning, and in the future, the incidence of such inquiries will undoubtedly increase. Whether to answer questions from parents, school boards, or teachers or to decide upon methods of implementation, professional educators must be adequately informed about developments in programmed materials. In planning this conference, we hoped to provide local educators an opportunity to obtain information from people who have had close contact with programming developments, and through this to aid all of us in preparing for our responsibilities in this area.

Many people are responsible for the success of the conference and the publication of this report. First of all, the support of the School of Education should be acknowledged. University Extension, through Mr. Jerry Adams, guided our plans and skillfully anticipated our needs for the conference. Dr. A. J. Edwards acted as recorder for the panel discussion and editor for the report of that phase of the conference. And to Dr. Robert Ridgway, a special vote of thanks is due for originally suggesting the topic and the guest speaker for the conference, and for his many excellent suggestions as the conference plans were taking shape.

This report summarizes the papers presented at the conference and the discussion at the final session. The first paper at the conference, entitled "A Review of Audio-Visual Research," was presented by Dr. Kenneth E. Anderson, Dean of the School of Education, University of Kansas. Dr. A. J. Edwards, Assistant Professor of Education, next presented a paper on "Learning Theory and Programmed Learning—Problems of Implementation." Mr. Norman Crowder, Technical Director, Educational Science Division, U.S. Industries, then discussed various types of programmed materials and, in essence, answered the challenges presented in Dr. Edwards' paper. The final session of the conference was a panel discussion; the panel members were Mr. Crowder; Mr. Robert Johnson, Consultant for Programmed Materials, Encyclopaedia Britannica Films; Dr. Herbert I. Bruning, Director of Curriculum, Shawnee Mission High School District; and Dr. Kenneth Rothwell, Assistant Professor of English, University of Kansas. To all of these willing participants, for sharing with us their thoughts and experiences in programmed materials, we express our sincere appreciation.

As a special feature of this issue, there is included in the appendix, pages 33-48, a sample program which illustrates the branching technique (or intrinsic programming) advocated by Mr. Crowder. This sample program, written by Mr. Crowder, is reproduced with his permission, and we are extremely appreciative of this opportunity to present a sample "scrambled book." Readers who are not familiar with programmed materials may want to look over the sample before reading the articles. In any case, all readers of this issue will probably want to read through the sample, following both the correct answer sequence and some of the remedial branches.

Audio-Visual Research

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Major efforts to influence the science and mathematics curricula by all levels of government, by professional societies, by institutions of higher learning, and by an impressive array of National committees are manifest on every hand. This changing educational climate has been brought about by a complex of factors including the threat to national survival, a maturing scientific and technological society, and a reluctant abandonment of a traditional national provincialism.

> Although the changes in science and mathematics, both actual and proposed, are of major proportions, this fact has not produced any pronounced shifts in the nature or amount of the related educational research produced. In fact, one is impressed by the sparsity of the evidence adduced which would either affirm or deny the efficacy of many of the large experimental programs. There is obviously a need for a more thoroughgoing consideration of evaluative techniques and procedures and for the planning of comprehensive educational research efforts as part of these experimental programs which commit vast sums of money and the time of millions of pupils.[1]

The above quotation, which appeared in a recent issue of the *Review of Educational Research,* reflects the current situation with regard to research in the fields of science and mathematics. Many of the studies reviewed in this specific issue were concerned with audio-visual research in the teaching of science, and it will be the purpose of this paper to review only five of the studies which appeared or will appear in *Science Education* from 1956 to 1961. The sixth study was a research project supported by a grant from the United States Office of Education.

It is important at this point, however, to ask the question: Is not the central and underlying purpose of research in education the improvement of instruction? If this be the primary purpose, then the real problem is the evaluation of the outcomes of instruction via audio visual aids, teaching machines, and programmed learning. What are some important objectives or criteria of learning? These may be stated in many ways but are not the following almost all inclusive?

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[1] Kenneth E. Anderson and Herbert A. Smith. "The Natural Sciences and Mathematics." *Review of Educational Research,* 31 (June 1961) 234.

Has the learner:

1. acquired and retained useful and pertinent information of a factual nature?

2. acquired and retained a workable understanding of the principles or *big ideas* of an academic field?

3. learned to use intelligent methods in adapting to the problems of his life?

4. reached a level of understanding, application, and performance in the above three which is commensurate with his ability?

> . . . evaluation must be geared to objectives along a continuum from simple understandings and skills and limited adaptability to more complete understandings and complex skills and greater adaptability. Where we as students and teachers are on this continuum determines the evaluation procedures to be employed. As long as we operate on a rather low level of understanding near the lower end of the continuum, the ordinary evaluation procedures will suffice. A little thought and ingenuity, however, can lift us off the lower levels of evaluation and place us a bit higher on the continuum. As we and our students continue to move upward in an understanding of what we are trying to accomplish, the simpler procedures will no longer evaluate adequately the transfer of understandings and abilities of the pupils.[2]

Regardless of whether or not you subscribe to the above criteria of learning in terms of a continuum or spectrum, it is imperative that the purposes of a research study be couched in terms of sound learning objectives if the research study is to have a chance of being implemented into action.

In the pamphlet entitled *Analysis of Research in the Teaching of Science,* published by the United States Office of Education, one study appropriate to the discussion of the conference was cited "for excellence in dealing with one or more (in some cases, all) of the following aspects of craftsmanship in educational research—choosing a significant problem, validating data, using statistical analysis, and reporting."[3] The study cited was entitled: "An Inquiry into Some Possible Learning Differentials as a Result of the Use of Sound Motion Pictures in High School Biology."[4] This study, however, was

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[2] Kenneth E. Anderson. "Implementing Research Into Action." *Science Education,* 44 (April, 1960) 178-187.

[3] *Analysis of Research in the Teaching of Science, July 1956-July 1957.* U. S. Department of Health, Education, and Welfare, Office of Education, Bulletin 1960, No. 2, pp. 33-34.

[4] Herbert A. Smith and Kenneth E. Anderson. "An Inquiry into Some Possible Learning Differentials as a Result of the Use of the Sound Motion Pictures in High School Biology." *Science Education,* 42 (February, 1958) 34-37.

based on a previous study entitled: "Toward a More Effective Use of Sound Motion Pictures in High School Biology."[5]

The problem of this study is quoted verbatim from the article which appeared in the February 1956 issue of *Science Education*. It reads:

> After identification of the principles covered or stressed in the twenty films, an experimental design was developed in which films and principles were introduced into an experimental situation in order to determine the effectiveness of films *in contributing to the understanding and application of principles of biological science when different teaching procedures were employed.*
>
> Three groups were established as follows:
>
> *Group I.* A control group in which no films were shown or in which the teachers showed some films of their own choice.
>
> *Group II.* An experimental group in which students saw the films at intervals throughout the school year. Teachers in these classes made their own preparations for the showing of the films.
>
> *Group III.* An experimental group which saw the films at intervals throughout the school year bolstered by the emphasizing of the principles *covered* or *stressed* in each film. The teachers of these classes received the following directions with each film:
>
> "Enclosed are sheets listing thirty-four biological principles selected from W. Edgar Martin's list of 300 major principles of the biological sciences. You will note upon examination of the sheets that the numbers of certain biological principles are cited in black, and others in red. If the number of the principle is circled in black, that principle is covered in the film. If the number of the principle is circled in red, that principle is stressed in the film. It is important *before the showing of the film* that you point out the principles which will be covered in the film. Use the chalk board or other means to inform your students of the principles covered in the film. *After the showing of the film,* stress the biological principles in your teaching."
>
> Thus, three groups of classes were involved as follows: Group I, the Control Group; Group II, the Film Group; and Group III, the Films-With-Principles-Stressed Group. Thus, the problem became one of testing which method produced superior results in measured achievement during the period of one school year of instruction. The design adopted required that differences which might occur in performance of the three groups were to be tested for significance by assumption of the null hypothesis.[6]

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[5] Kenneth E. Anderson, Fred S. Montgomery, Herbert A. Smith, and Dorothy S. Anderson. "Toward a More Effective Use of Sound Motion Pictures in High School Biology." *Science Education,* 40 (February, 1956) 43-54.

[6] *Ibid.,* pp. 46-7.

One of the interesting analyses of the data in the above study may be summarized as follows:

> An interesting area of speculation in the interpretation of an experimental study is suggested by Lucow who said: "It is here suggested as a postulate in educational philosophy that greater variation in classroom achievement is evidence of the release of individual differences among pupils during the learning process." Lucow went on to say: "A change in variance from pre-test to after-test was considered to be of greater import than the change in means, under the assumption that greater variance in a group indicated greater expression of individual differences."
>
> Which of the three methods as used in this study produced the greatest change in variance from the pre-test to the post-test? In order to answer this question, it was necessary to establish a confidence interval for the ratio of post-test variance to pre-test variance for each of the three treatment methods.[7]

The results of the above study were summarized as follows:

> On the basis of the three techniques of statistical analysis used in this study, and within the limitations imposed by the tests employed, it may be concluded that:
>
> 1. No differences in achievement existed between the three treatment groups holding intelligence test scores and pre-test scores constant. This conclusion must be tempered by the fact that thirteen of the sixty groups could not be used in the analysis because of failure to meet one or more of the assumptions basic to the design of the investigation.
>
> 2. Differences in achievement existed between the treatment groups of the upper one-third in intelligence as measured and that these differences were in favor of the Group III or the Films-with-Principles-Stressed Group as contrasted to Groups II and I or the Film Group and the Control Group. The same conclusion applies for students in the lower one-third in intelligence as measured but the differences were not as marked.
>
> 3. Another index of the superiority of Method III to Methods II and I was found in the increase in variance from pre-test to post-test. Method II was superior to Method I in this same respect.
>
> Thus, there is some evidence that the Films-with-Principles-Stressed Method yielded results somewhat superior to the Film Method, and that the Film Method yielded results somewhat superior to a conventional method as used in the Control Group.[8]

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[7] *Ibid.*, p. 51.

[8] *Ibid.*, pp. 52-4.

Another study appropriate to the discussion of the conference was one entitled: "An Evaluation of the Introductory Physics Course on Film."[9] The problem of this study was:

> The problem was one of testing which method produced superior results in measured achievement during the period of one school year of instruction: the conventional method or the film method of instruction. The design adopted required that differences which might occur in performance of the two groups were to be tested for significance by assumption of the null hypothesis.
>
> In order to secure necessary data as a basis for a statistical test of the null hypothesis, it was decided to administer three tests as follows:
>
> 1. The *Dunning Physics Test, Form Am,* World Book Company, as a pre-test at the beginning of the school year, 1958-59.
>
> 2. The *Dunning Physics Test, Form Bm,* World Book Company, as a post-test at the end of the school year, 1958-59.
>
> 3. The *Terman-McNemar Test of Mental Ability, Form C,* World Book Company, as an intelligence test during tne middle of the school year, 1958-59.[10]

The three hypotheses under test in the form of questions were as follows:

> 1. Did the experimental classes achieve significantly more than the control classes with intelligence quotients and pre-test scores held constant?
>
> 2. Did the students of the experimental classes with above average, average, and below average intelligence quotients achieve significantly more than their counterparts in the control classes?
>
> 3. Did the students in the experimental classes evidence a significantly greater change in variance from the pre- to the post-test than did the students in the control classes?[11]

The results of the above study were summarized as follows:

> The data presented in this study would lead one to conclude that the film method produced somewhat greater variability in achievement than did the conventional method. Therefore, in proportion as this is true, the film method was superior. Also, it seemed to produce greater variability than the conventional method for students in the I.Q. ranges 113-124 and 113 and below. Thus, one may conclude that the film method was superior to the conventional method for those groups of students.

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[9] Kenneth E. Anderson and Fred S. Montgomery. "An Evaluation of the Introductory Physics Course on Films." *Science Education,* 43 (December, 1959) 386-394.

[10] *Ibid.,* p. 386.

[11] *Ibid.,* p. 387-9.

> The reactions of the teachers and the students would seem to indicate that there were too many films and that it would be a better procedure to select and show films once or twice a week. The films selected should be those for which equipment is not available and those that demonstrate principles and theories difficult to present in a typical high school classroom.
>
> The conclusions of this study must be tempered by the fact that only the classes in two large selected schools were used. However, the use of two schools similar in size, purpose, and community background would tend to minimize the effect of these variables. No attempt was made to secure a random sample of physics classes in the State of Kansas since the cost of a set of films and distribution of the films to a large number of schools would have been difficult.
>
> The results of this study parallel quite closely the results as obtained in the *Wisconsin Physics Film Evaluation Project* in which 30 control and 30 experimental schools were selected at random.[12]

The same investigators completed three companion studies[13, 14, 15] involving a year-long study of the effectiveness of the Encyclopaedia Britannica Film Course on Chemistry. About 600 students of chemistry in the five Wichita high schools of Wichita, Kansas, were involved. A total of 33 chemistry classes participated in the study and nine teachers taught the 33 classes. Although three teachers taught both film and non-film classes, the mean number of semester hours of preparation in college science was 68 for the non-film teachers and 51 for the film teachers. The mean number of hours of preparation in college chemistry was 35 for the non-film teachers and 25 for the film teachers. The non-film teachers had on the average, 20 years of teaching experience as contrasted to seven years of teaching experience for the film teachers. Thus, as these factors influence achievement in chemistry, the balance was in favor of the non-film classes.

The thirty-three classes were composed of seven film classes and 26 non-film classes. In the case of the 26 non-film classes, the number was reduced to eight by combining the classes of each teacher. No statistical violence was done since an inspection of the means and variances for the criterion measures

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[12] *Ibid.*, p. 393-4.

[13] Kenneth E. Anderson, Fred S. Montgomery, Sid F, Moore. "An Evaluation of the Introductory Chemistry Course on Film." *Science Education,* 45 (April 1961) 254-69.

[14] Kenneth E. Anderson, Fred S. Montgomery, and Dale P. Scannell. "An Evaluation of the Introductory Chemistry Course on Film by Factorial Design and Covariance with Method and Sex as the Main Variables." *Science Education,* 45 (April 1961) 269-74.

[15] Kenneth E. Anderson, Fred S. Montgomery, and Dale P. Scannell. "An Evaluation of the Introductory Chemistry Course on Film by Factorial Design and Covariance with Method and Career Plans as the Main Variables." *Science Education,* 45 (April 1961) 275-78.

used in the study appeared to be relatively homogeneous. Thus the final composition of the groups used in the comparison were eight non-film groups and seven film groups.

The problem in the first study was one of testing which method produced superior results in measured achievement during the one school year of instruction: the conventional method or the film method of instruction. The design adopted required that differences which might occur in performance of the contrasting groups were to be tested for significance by assumption of the null hypothesis. Several specific null hypotheses were tested as follows:

1. Did the Film Groups Achieve Significantly More than the Non-Film Groups on the *Anderson Chemistry Test* with SCAT and Pre-Test Scores Held Constant?

2. Did the Film Groups Achieve Significantly More than the Non-Film Groups on the *A.C.S.-N.S.T.A. Chemistry Examination* with SCAT and Pre-Test Scores Held Constant?

3. Did the Film Groups Achieve Significantly More than the Non-Film Groups on the *Laboratory Techniques and Apparatus Test* with SCAT Scores Held Constant?

4. Six of the groups at one high school were given the *Anderson Chemistry Test* as a pre-test, mid-year test, and post-test. Were the gains from pre-test to mid-year test and from the mid-year to the post-test greater for the three film groups than for the three non-film groups?

5. Three teachers taught both film and non-film classes. Did the Film Classes Achieve Significantly More than the Non-Film Classes on:

A. The *Anderson Chemistry Test* with SCAT and Pre-test Scores Held Constant?

B. The *A.C.S.-N.S.T.A. Chemistry Examination* with SCAT and Pre-test Scores Held Constant.

C. The *Laboratory Techniques and Apparatus Test* with SCAT Scores Held Constant?

In order to secure necessary data for a statistical test of the null hypothesis, it was decided to administer four tests as follows:

1. The *Anderson Chemistry Test, Form Am,*[16] as a pre-test, mid-year test, and post-test at the end of the school year.

2. The *Laboratory Techniques and Apparatus Test for High School Chemistry*[17] as a post-test at the end of the school year.

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[16] Published by the World Book Company, Yonkers-on-Hudson, New York.

[17] Published by Kenneth E. Anderson, Dean, School of Education, The University of Kansas, 1960.

3. The *A.C.S.-N.S.T.A. Cooperative Examination—High School Chemistry Form 1959* as a pre-test and post-test.[18] Part I was used as a pre-test and Part II was used as a post-test.

4. The SCAT or *School and College Ability Tests*.[19] Total score on this test was used in the calculations.

Raw scores obtained from these tests, were used in the statistical analyses which follow. All pre-tests were administered during the first two weeks of the school year and all post-tests were administered within the last two weeks of the school year. The SCAT and mid-year chemistry tests were administered at the mid-point of the school year.[20]

Space does not permit a resume regarding each null hypothesis tested. However, the results may be summarized as follows:

The data presented in this study would seem to indicate that the students in the non-film classes achieved more in high school chemistry than did the students in the film classes. This statement is supported by the fact that in eight of the seventeen direct comparisons, the differences in measured achievement were significant and in favor of the non-film groups. Only three out of the seventeen differences were significant and in favor of the film groups. This was especially true for the *A.C.S.-N.S.T.A. Chemistry Examination* where five of the eight comparisons were significant and in favor of the non-film groups. The results were about equally divided in terms of the *Anderson Chemistry Test*. This may be due to the fact that the tests measured somewhat different abilities in chemistry. Two of the five comparisons for the *Laboratory Techniques and Apparatus Test* were significant and in favor of the non-film groups. Only one comparison was significant and in favor of the film groups.

When gains were compared on the *Anderson Chemistry Test* from the pre-test to the mid-year test and from the mid-year test to the post-test, there was some indication that the non-film groups were somewhat superior and that the film groups suffered a greater drop in achievement during the last half of the year than did the non-film groups. The students' reaction would seem to indicate that too many films were shown and that boredom had set in. This may account for the film groups greater drop in mean gain during the last half of the year.

When the film and non-film groups taught by the same teacher were compared, the results were in favor of the non-film groups. Four out of the nine comparisons were significant and in favor of the non-film groups.

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[18] Published by the Examination Committee—A.C.S., St. Louis University.

[19] Published by the Cooperative Test Division, Educational Testing Service, Princeton, New Jersey.

[20] Kenneth E. Anderson, Fred S. Montgomery, Sid F. Moore. *op. cit.*, p. 254.

Only two of the nine comparisons were significant and in favor of the film groups.

The students in the film classes were asked to give their reaction to several questions and in general one might say that the students felt they would have done better in a conventional chemistry course. Evidently, the students in the film group missed the usual laboratory instruction since about 83 per cent would have liked more laboratory work. The students felt they might have done better had they used a textbook designed to accompany the films rather than using the textbook employed with the non-film groups.

The students thought the film instructor was excellent and that the colored film added a great deal. They also felt that the experiments shown in the films used excellent equipment not usually available in a high school laboratory. They felt that the use of this equipment and the fine execution of the experiments was something they would have missed in the conventional laboratory approach. They also liked the wide range of industrial applications of chemistry shown in the films. They felt that this was quite broadening and stimulated their interest in science.

The students felt there were too many films but almost an equal number would be willing to take another film course.

All in all, despite the better achievement of the non-film classes on the chemistry examinations used, one cannot say that the student's reaction was negative. In fact, they felt that they had gained much by being in the film classes.

Several of the students, and apparently the better students, felt that a better procedure would be a wise selection of the films by the teacher in terms of: (1) his preparation to teach chemistry, (2) the equipment and facilities available, and (3) the ability of his students to master the level of chemistry he is able to present.[21]

The two companion studies published in *Science Education* in April make use of "multivariate analysis" in the form of a factorial design employing analysis of covariance in the statistical analysis.

In these studies, the sample of schools chosen were not representative of the schools of Kansas but consisted of the five large high schools in Wichita, Kansas. However, if the chemistry classes in these schools are considered as the sample, and if the students had been assigned to film and non-film classes by random means, then the scores of the forty students selected at random from the four sub-populations would constitute a representative sample. The survey evidence, therefore, secured from the statistical analyses, would have provided a valid basis for generalizations about all of the chemistry students in Wichita in terms of the variables under consideration.

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[21] *Ibid.*, p. 267-8.

Actually, ten students were selected by means of random numbers from four sub-populations as follows:

1. First Study:

Film Method-Male	79
Film Method-Female	49
Non-Film Method-Male	289
Non-Film Method-Female	173

2. Second Study:

Film Method-Science Career	65
Film Method-Non-Science Career	62
Non-Film Method-Science Career	190
Non-Film Method-Non-Science Career	373

The ten scores in each study were placed in one of the cells of a 2 x 2 table as follows:

1. First Study:

Group	Male	Female
Film		
Non-Film		

2. Second Study:

Group	Science Career	Non-Science Career
Film		
Non-Film		

The statistical technique used was that of analysis of covariance in which raw scores on the pre-test (*Anderson Chemistry Test,* World Book Company) and raw SCAT scores (*School and College Ability Test,* Educational Testing Service) were controlled.

The results of the analyses yielded the following conclusions:

1. First Study:

   The non-film group achieved significantly more than the film group with pre-test and SCAT scores held constant. Since the F values for sex and interaction were not significant, the conclusion was not biased by the factor of sex nor influenced by an interaction between sex and method.

2. Second Study:

> The film and non-film groups achieved the same with pre-test and SCAT scores held constant. The science career students achieved significantly more than the non-science career students with pre-test and SCAT scores held constant, since the F was significant at the 5 per cent level and the adjusted means were 53.35 and 45.95 respectively. Since the F values for method and interaction were not significant, the conclusion was not biased by the factor method nor influenced by interaction between method and career. Since the F value for career was significant, control of this factor by stratification was justified.

Thus, in conclusion, it may be seen that the limits of the analytic survey may be extended to more advanced designs in which several main variables may be involved. In this way, it will be possible to vary all the essential conditions simultaneously rather than one at a time, thus resulting in greater efficiency and comprehensiveness. The results, therefore, have wider applicability than do single-factor comparisons since the ordinary analysis gives information only in respect to a narrowly restricted set of conditions.[22]

An excellent study by Popham and Sadnavitch entitled "An Analysis of Filmed Science Courses in Public Secondary Schools," concludes:

> The results of this investigation seem to raise doubts concerning the value of the filmed science courses, at least as they were employed in this experiment. This was particularly true in the case of the physics series. Of course, the many limitations associated with a single research project such as the one described herein do not permit one to draw definitive conclusions. However, research findings such as these should make it incumbent upon proponents of the filmed science courses to supply empirical evidence that the filmed technique produces educational gains which are at least comparable to those yielded by ordinary instructional methods. With a view to sound fiscal policies in the secondary school, the considerable cost associated with the purchase of the filmed science courses should dictate that more evidence supporting their effectiveness must be presented before a favorable judgment regarding the educational usefulness of the films can be reached.[23]

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[22] Kenneth E. Anderson. "Analytic Surveys." Address given at the 34th Annual Meeting of the National Association for Research in Science Teaching, Chicago, Illinois, February 20, 1961.

[23] W. James Popham and Joseph M. Sadnavitch. "An Evaluation of Filmed Science Courses in Public Secondary Schools." Paper read at the Annual Meeting of the American Educational Research Association, Chicago, Illinois, February 23-25, 1961.

Thus the results of these six studies, although essentially negative, raise some interesting speculations. In the first study entitled "Toward a More Effective Use of Sound Motion Pictures in High School Biology," the teachers and students were made aware of the principles of biological science covered or stressed in each film. The focus of the instruction was on the principles and the teaching, therefore, was purposeful. The results, discounting any "Hawthorne Effect," would seem to indicate that when the instruction via films is purposeful and planned in terms of objectives to be reached, positive increments in learning occur. One might also say that films should not replace the regular mode of instruction or the role played by the instructor. Teaching with or without films, television, or machines, will be effective only as we employ teachers who know their subject matter and have the know-how to put the material across. A good teacher may greatly augment his effectiveness by the proper use of mechanical aids. This means selection of good films, good television programs, and good teaching-machine programs, which fit into a planned and purposeful program of instruction, the objectives of which are known by both the teacher and her students and which are above the fact-knowing level or which are challenging to both parties in the instructional process. Without these considerations, the process of learning is no better off than it was before the day of mechanical aids.

In conclusion, I quote:

> Generally, studies in educational television give little or no consideration to the factors enumerated above. As a result, an individual has difficulty in determining their meaning. It is even conceivable that the effects of television teaching are to limit seriously the amount of learning that takes place in the classroom but that this deleterious effect is sometimes compensated for by the tutoring and the extra motivation which the procedure invokes. While this is an extreme hypothesis which probably should not be taken seriously, its compatibility with the findings in current studies in the area of educational television point to the deficiencies of such research.[24]

[24] Robert S. Soar. "Evaluating Educational Television." *The University of South Carolina Education Report,* 4 (December, 1960) 3-4.

Learning Theory and Programmed Learning: Problems of Implementation

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The purpose of this paper is to raise some issues regarding uses and outcomes of teaching machines and programmed learning. In so doing, I am aware that it is always easier to ask questions than to answer them. It is also true that these same issues and questions may be raised with respect to any teaching aid and, more basically, to any teaching-learning situation. I feel that classroom teachers are too little aware of these issues in respect to their own teaching, so that I do not intend my remarks to be detrimental to the use of machines and programs, only questioning. Whether or not all the issues can be clarified in a one-day session by those who will speak more directly about programmed learning, I am not at all sure. I do feel, as an educational psychologist with a primary interest in learning, that these issues and questions should be foremost in the minds of school personnel intent upon experimentation and use of programmed machines. For the record, may I state a personal bias at this point: From the standpoint of classroom learning, I hold very high hopes for teaching machines. The potential for acceleration and utilization of intellectual abilities in classroom situations seems great to me, when machines and programs are adequate and applicable. This attitude does not prevent me from having a questioning nature and urging that we make haste slowly. The utility of programmed learning will be demonstrated primarily through experimentation, with adequate controls, in classroom situations.

In the time which I have, I should like to mention briefly factors in two areas. The first of these is usually considered the more practical by school personnel and concerns a basic issue of economy. By economy, I mean not only monetary, as important as this is, but also economy in the form of adaptability and usability of both machines and programs. This will also include some remarks relevant to function of programmed learning in academic programs.

The second factor will deal with learning parameters, or variables associated with learning. Specifically, these include provision for differences in intelligence; the motivational variables of purpose in learning, interests, rewards, information-giving and degree of motivation; and formal learning characteristics, including learning rate, practice, review, retention, and transfer and generalization.

Administrative Concerns in Using Machines

The first questions to be raised in conjunction with automated teaching are primarily, but not completely, administrative concerns. I consider them administrative because they apply to the over-all role of teaching aids in public school programs. In making a decision about using programmed machines in part or all of the academic program, these issues must be decided upon their own merits.

The first of these issues deals with the problem of economics, a straightforward question as to whether the gains in learning (if any) are sufficient in terms of capital outlay both for machines and programs for machines. In the public schools, already harassed by financial problems, this question cannot be dismissed. There must be evidence supplied that the channeling of funds into the new area yields sufficient return. I suspect this is a problem which must be investigated and answered by school systems, perhaps through grants, rather than by manufacturers and distributors of machines and programs.

There are problems of administrative economy other than the monetary one, as well. Chief among these, to me, is one of adaptability. School people must ask questions such as these: Are the machines limited in their use to a specific group? Are the programs available useful for the general case and therefore limited in their usefulness with the extremes? Are changes possible in programs by specific teachers, and under what conditions? Can programs be constructed by individual teachers, or by some individual responsible for such a process in the school system? Do the programs apply to processes and facts only, or do they also reflect problem-solving and generalization processes? There are probably other questions which might be raised, but these are representative of what I consider an adaptability concern from the administrative viewpoint. May I point out, too, that I do *not* believe the answers to all such questions must be positive for programmed learning to be considered feasible by school personnel. The answers to such questions must influence a decision about utilizing machines, however. The less adaptable administratively, the weaker the case for using machines. My own hunch is that we may get positive answers to a number of these questions when they are experimentally studied.

The question of usability is also economic in nature. The principal concern here is of application to specific courses or kinds of courses and to the school level or grades with which programmed teaching might be used. Administratively, if machines are adaptable only for certain courses (such as math and science) and not for other courses (such as English and history), their utility may be limited. At the same time, the more grade levels with which the machines may be used and for which programs are available, the better the case, administratively, which may be made for their inclusion in curricular planning.

A final question in this area which I would raise deals with the function of machines in academic programs. In any course, or series of courses, there are academic goals and objectives which are established. These goals are both short-term and long-range in nature. School personnel are interested in immediate effects through incorporation of knowledge. As an educational procedure, this is necessary but not sufficient. There are long-range goals, reflected in examining immediate knowledge through perspective to its applicability to many areas. The question must be raised: Are we insuring high levels of immediate knowledge to some detriment of future use? School personnel are aware that, by utilizing certain techniques, we can "look good" to the general public because students have a facile manipulation of processes. Fortunately, school personnel are not willing generally to settle for this, since it is not an adequate representation of knowledge and learning. There must be some comparison of general long-range effects and specific immediate effects with programmed learning.

Essentially, the questions I have raised from an administrative standpoint may be reduced to one of general scope: In comparison with current achievements, and lack of them, academically, how will programmed instruction measure up? If it allows a better job, then school personnel must incorporate machines in the curriculum. If not, programmed learning has little to offer.

Learning Parameters and Teaching Machines

Some attention must be given now to the kinds of questions relevant to the classroom. In our public schools today we have all kinds of learners: bright and not so bright, eager and not so eager, in attendance and not in attendance, learning and not learning so much, remembering and not remembering so well. From a philosophical point-of-view, no one learner is any more important than any other. From the practical point, if we can find a device or technique which will produce better classroom results, by all means let's use it. In any event, disparity is the rule in public education and no one honestly expects it to be reduced whatever we do. To be functional, then, programmed learning and automated teaching must fit itself to several variables that affect learning.

Intelligence. The first of these concerns intellectual ability. Nearly all children of elementary-school age are enrolled in school and some 75 to 80 per cent of those of high school age. The nature of intelligence being what it is, we expect to find bright, average and dull learners in any classroom. Even if some grouping procedure which places emphasis on ability is used, there still must exist wide variability in intelligence. The importance of this variable for classroom learning is such that a major area of concern in education is provision for individual differences. As in any other question concerning programmed learning, the teaching machine itself is not the im-

portant element. The machines commonly advocated for classroom use are simple enough in construction and operation that even learners in special classes for the retarded should be able to learn to manipulate them. The important element, then, is the program. In the regular classroom, with its variability in ability, a single program might have to be designed in terms of the characteristics of the slower learners. Either that, or have several programs for the various levels of ability. In one approach to programming, the program is built in such a sequence that "failure" (i.e., incorrect responses) will not exceed 5 per cent. If this approach is used, all learners proceed through the same sequences. It is true that intellectually brighter individuals will move through such a program more quickly. Even so, this approach seems insufficient in its appreciation of intellectual levels. The other approach allows for "branching"; i.e., certain portions of the learning material may be skipped over as mastery of material is demonstrated. This latter approach seems more satisfactory from the standpoint of differences in ability. At least a provision is intrinsic in the program for brighter individuals who will tend to learn more quickly.

If courses are sectioned by ability levels and if special classes exist for gifted and retarded learners, different programs should be used in differing classes. School personnel, in considering programmed learning, must think in terms of the intellectual abilities of students. One program for a course will probably prove no more satisfactory than one textbook for all students in a course is proving today.

Motivation. The second variable, motivation, actually includes several elements relevant to teaching-learning situations. The first element is the establishment of purpose in learning. Currently, teachers may spend considerable time in establishing purpose so that the individual learner sets out with some immediate goals which are apparent to him and may be reached. This is done through tying-in old learnings with the new, showing the learner where he is and where he is going. Such a procedure will still be necessary in the use of programmed learning. There may be one difference, however; the purpose established by the teacher will be in conjunction with a given program. Immediate purpose currently is used by teachers to involve the learner temporarily—the teacher does not depend solely upon this. New purposes must be established as the learning proceeds, and this purpose tends to become more general, broader, more inclusive of large-scale instructional goals. The question arises as to whether programs currently available or to be available will contain the same possibilities. A program can assure sequence, success, immediate learning goals. If restricted to this, the teacher must plan and teach still in such a way as to expand purpose and keep it active.

The second element concerns interest. Most learners are attracted by the novel, the new, without regard really to learning material itself. Such appeal

to interests also may act as a wedge to learning and is utilized frequently by teachers. There is no doubt that teaching machines, when first used in a classroom, will have such appeal. As a result, increments in learning may be shown superior to that found in the regular classroom procedures. But novelty loses its appeal. Under such circumstances, the increments in learning will disappear. Teaching machines must demonstrate more than just immediate appeal. But the concept of interest is more profund even than this. One of the expected outcomes of successful learning experiences is that the learner will develop more lasting interests in a subject, pursue it independently, and broaden it more widely than a formal course can ever accomplish. Basic to this accomplishment is experience with a subject and some degree of success. Teaching machines and programs successfully fulfill these two requisites. Yet we know that experience and success with a subject do not assure a lasting interest. There are other important elements, not the least of which is the personal one. Many students become interested in subjects, not simply because of what they learn, but because of the teacher. As with purpose in learning, this goal of permanent interests will still depend upon teacher interaction with students. It is really not the purpose nor the scope of machines to accomplish such goals as these. This, then, is not a requirement of programming. It illustrates the fact that teachers will still be faced with many of the same problems using machines as they are today and in certain ways these problems will be intensified.

All motivational elements are not outside the sphere of influence of programmed machines, however. As a matter of fact, some of the strongest points to be made for machines lie in reward and information-giving. There is great appeal to the fact that a learner knows immediately whether his performance is correct or incorrect. When this response is correct, the reinforcement proves beneficial to the learning. This is probably the strongest point to be made for incremental steps in the program, since there must be a very low percentage of incorrect responses. For teachers who subscribe to a reinforcement theory of learning, this point alone makes the programmed learning approach worthwhile. There is a point to be made, however, for the fact that learning can occur through failures as well as successes. This is particularly true when immediate knowledge of results is given and correction is instituted. The positive effects of immediate information-giving cannot be overemphasized. In many school learning situations, learners must wait some length of time before knowing the success of performance and to learn where failures occur. Other learnings have occurred in the meantime so that the knowledge is less beneficial. Much of the writing emphasizing the value of automated teaching has stressed these points. There is little doubt that programmed learning can provide more adequately in these areas than a classroom teacher, under current educational procedures, ever can.

There may be a negative point to be made, however. Much of the research dealing with incentives indicates that over-use of any particular incentive,

either positive or negative, tends to cause it to lose effectiveness. If a learner meets only success in conjunction with learning, may he tend to become neutral toward the subject? Personally, I doubt it, since the research done on incentives has utilized externally imposed treatments. With programmed learning, the appeal is to intrinsic values and the success would involve more personal elements. There is a little research indicating that some learners experiencing consistent success tend to become over-motivated in this direction, and find it difficult to accept any form of criticism or failure. The level of aspiration of the individual is thus not very realistic. Will programmed learning, offering greater chances for success, accentuate such behavior in individuals? At this stage, no one can say. These kinds of questions reflect a human, personal element which machines and programs cannot approach. This does not lessen the importance of the questions to the teacher in considering uses and outcomes of programmed learning, however.

Formal Learning Characteristics. Intelligence and motivational elements affect formal learning, but only indirectly. They are not usually considered a part of formal learning characteristics as such, so that elements more specific to learning must also be considered. The first of these is rate or speed of learning. All youngsters do not learn at the same rate, and though these differences show a high relationship with levels of intelligence, the factor of learning must be considered independently. This is true because we must consider such an aspect as meaningfulness in learning materials. The more meaningful the material to be learned, the more quickly it is learned. A capable learner will not learn all material at the same rate, due to influences of such factors as vocabulary used, technical terms, means of expression, and so on. A crucial element in meaningfulness is familiarity. Generally speaking, the more familiar materials are, the more easily will they be learned by a learner of any intellectual level. Given two learners in most school situations: When presented with the same learning material, they must differ in learning time. Even if material is made familiar to them on their intellectual levels, learning rates will still differ. The concept of meaningfulness, including familiarity, must be incorporated in programmed learning if it is to be successful.

In the same way, practice is a variable influencing learning. All learners do not need equal amounts of practice to achieve mastery. As a matter of fact, it has been pretty well demonstrated that practice, in itself, accomplishes little. It only allows other things of importance to learning to occur. Generally speaking, less capable learners need more practice. Programmed learning may make a contribution here that classroom teachers are unable to achieve at the present time. A "slow learner" given an adequate program may be able, in conjunction with the learning speed factor, to successfully reach learning goals. But more capable learners need less practice. Overpractice, even when successful, sometimes leads to boredom and rejection of the task. What is called for is an optimal amount of practice to reach a

learning goal with some opportunity for over-learning. Frankly, present classroom procedures do not allow this. If automated teaching can be demonstrated to do so, a strong case will be made for its adoption in classrooms. There will be wiser use of learning time for individual types of learners.

The opportunity for review assumes importance as well. Since forgetting is so pervasive, review procedures are necessary. Even more immediately, however, the question must be raised about opportunities for review of some elements already passed or by-passed in the program. Sometimes a learner will feel a need to go back and review some elements, or the teacher will recognize such a need. Is this possible using teaching machines, or will it be necessary for the teacher to carry out such activities independently of the programmed learning? Certainly before committing oneself to extensive use of teaching machines, this question must be answered.

There is the question of retention as well. We expect forgetting to occur. What provisions are to be made within programs for the fact that there will be forgetting? Using an active recall process, currently, a learner can review only those elements in the material which he does not retain. To offset the effects of forgetting, must a learner periodically go through an entire program on a teaching machine? This seems a waste of time and effort if it is necessary. One of the most disturbing claims in an advertisement appearing for one kind of programmed machine last year, to me at least, was the claim that a student had perfect retention of material after several months. If this did occur, I suspect it is a rarity. There must be some study of forgetting when automated teaching is used. Though there is rarely, if ever, permanence of learning, the effects of learning are pervasive. Is this true with programs as well?

This leads me to one final area: transfer and generalization. Educational procedures are concerned with facts and processes, because these are necessary for adequate generalization to take place. One of the criticisms frequently found in literature opposed to the use of machine teaching is that programs must be confined to facts and processes. Much of the educational procedure, and probably the most important part, is the utilization of acquired knowledge in other areas. Teaching machines, to be accepted educationally, must provide for a transfer process, or it must be explicitly stated that teachers must still make provisions for transfer. The ability of programs to provide for higher cognitive processes must be tested. The acceptance of programmed learning will depend as much upon a frank statement of limitations as upon strengths.

As I mentioned in beginning this paper, my personal attitude toward the use of automated teaching devices is a positive one. At the same time, I do not see this area as a panacea for educational ills. Any teaching aid which may prove beneficial to educational procedures must be given serious consideration. This "serious consideration" includes an evaluation by school personnel of the variables I have mentioned.

Characteristics of Branching Programs

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I would like to say at the outset that I am gratified by the reference in Dr. Edwards' thoughtful paper to the fact that there are a number of unsolved questions in education that are the property of the whole field of education, rather than being specifically the concern of the proponents of teaching machines. Sometimes it seems that we advocates of "learning engines," as one of our British editors calls them, are expected to have solved questions of educational objectives, measures of achievement of such objectives, and a host of related problems which do not properly fall within our area of competence or responsibility.

It would be presumptuous for me, as a developer of teaching machine techniques, to say to educators, "This is what you ought to want to achieve." It would also be premature, at the present time, for me to say definitely that this or that is what can be achieved by given methods. What can be done is to explain the characteristics of the techniques with which we are presently working, and relate the experience we have had to date. It is then up to the educator to decide whether the techniques offered seem likely to achieve the results that he, as an individual educator, desires.

There are, of course, several schools of thought about how teaching machines ought to be constructed, and these schools rest on quite different theoretical bases. I can only speak for the school with which I have been identified, and my remarks in the rest of this paper should be construed as referring primarily to the work of that school. The technique involved has been called "intrinsic programming" and is also frequently identified as "branching programming."

The technique of intrinsic programming was conceived as a direct result of an analysis of the process of private tutoring. I was working in an Air Force research program on the problem of training "troubleshooters," i.e. diagnosticians, to find malfunctions in complex electronics equipment. Preliminary study showed that this training had always been done, to the extent that it had been done at all, by what amounted to a tutoring, or "coach and pupil" method. Since it was clear that the armed forces could not afford a sufficient number of skilled tutors to train the troubleshooters required, we set about to find means of reproducing this training situation without requiring a tutor for each student. The intrinsic programming technique was the direct result of these efforts. I mention these historical circumstances to make two points: first, that the technique I will discuss arose out of study of an actual training problem, and second, that the training involved was training in a complex problem-solving process.

When we consider what an individual tutor does in working with a student, we found our attention focussed on three kinds of activity. We found that the tutor (a) presented new information to the student; (b) required the student to use this new information, usually to answer questions; and (c) took appropriate action on the basis of what the student did, either going on to new information if the student performed correctly, or going back and reviewing or re-presenting the old material, perhaps in a more thorough or simplified fashion, if the student did not demonstrate mastery of each piece of information.

We have these three functions, then: (1) the presentation of material, (2) the examination of the student, and (3) advancement, or the taking of corrective action if necessary, which we must build into an automated device if it is to take the place of the live tutor. It turns out that these three functions can be achieved with relatively simple devices.

The simplest device having all three of these functions is what was originally called a "scrambled book" and what we now refer to as a TutorText.* It is a specially prepared book in which the pages are not in any logical order, but through which the student must work by answering questions. On Page 1 of the book, the student finds the first piece of information and the first question. The question is in multiple-choice form, and there is a page number given for each answer choice. The student chooses whichever answer he thinks is correct, and turns to the page number given with that answer. If he has chosen the correct answer, he will find himself on a page that gives the next piece of information and the next question. If the student has chosen an incorrect answer, however, he will find himself on a page which was specifically written to correct the particular error he has made. Following the corrective material, the student is directed to return to the original question page to try again. Perhaps this process will be best explained by an example of some actual material prepared in this form. (Mr. Crowder at this point referred to the sample sequence "A Theorem In Number Theory," which is reproduced in the Appendix, pp. 33-48. The reader might desire to work his way through that sample at this point.)

We see in this sample, then, how these three functions, presentation of material, testing of the student, and automatic correction or advancement of the student can be achieved in this relatively simple TutorText* format.

There are several points that should be made about this type of material in its simplest form. In the first place, let me point out that the technique is actually quite conventional in its details. We confront the student with symbolic material; we expect that, in some unspecified way, reading this material

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will equip the student with the ability to answer a question on the material he has read; we test the student immediately to see if he did, in fact, learn the material presented; and, finally, we either advance to the next point, or return and re-teach the present point, as indicated by the test result. My reason for stressing the familiarity of the details of this process is to dispel any aura of mystery surrounding what we are attempting to do or the means by which we expect to achieve results. I do not claim to be privy to any startling new discovery about how the human mind works, or how students learn. The process involved is the old familiar process of teach, test, and correct if necessary—a process that teachers have used for years. What is new is the organization of the material in such a form that the teach-test cycle takes place once every minute or two instead of once a day or longer, and is automatic in the sense that no direct intercession on the part of the teacher is required in the cycle. I shall not belabor this point further except to mention that we are dealing here not with a new theoretical discovery about the nature of human learning, but merely with a new means of putting into practice principles in which we have long believed, i.e. that any instructional program must include frequent evaluation of the student's progress, and that when such an evaluation is made, appropriate action should be promptly taken. What we have in this particular kind of programmed instruction is the practical means to put these old and well-known principles into practice.

I have been stressing the point that we make use of the student's responses throughout the program for a testing purpose, although of course our object is not to assign the student a grade, but rather to modify the instructional program automatically to meet the manifest needs of a given student. However, it is obvious that the fact that the student is required to perform (by answering questions) at frequent intervals in the program serves other useful functions as well. For one thing, it requires the student to be an active participant in the learning process, rather than to be merely a passive recipient of information. The required activity doubtless has a useful practice effect. More importantly, however, the requirement to answer questions throughout the course of the programmed material enables the student to see what it is that we expect him to learn and also allows him to see that he is learning. Too often, I fear, students in conventional learning situations are unable to form a clear conception of exactly what they are expected to learn from a given lecture or piece of assigned reading. By including frequent questions we let the student in on our instructional purposes, which is all to the good. Finally, we find that when the student can see, by answering questions correctly, that he *is* learning and thus making progress, motivation remains at a very high level. The inclusion of the requirement for frequent student performance, then, serves a number of useful functions in addition to the testing function required to automatically adapt

the programmed material that primarily distinguishes intrinsically programmed material from the type of programmed material advocated by Dr. Skinner and his followers.

I think I should mention, in connection with the motivational function served by the questions in the material, that I have never been an advocate of questions so easy that the learner rarely, if ever, makes an error. I believe that the questions should be of sufficient level of difficulty that the student has the feeling of earning the satisfaction that he receives from getting an answer correct, and I think experience is accumulating that shows that if the questions asked are too easy the student loses motivation after a while. Related to this question, of course, is the matter of providing for individual differences among the students. It is perfectly clear that if we were to construct a program in such short and simple steps that the dullest, or even the average student, got almost all the questions right, we would be going at much too slow a pace for our bright students. It is one of the most attractive features of automated instruction that we can now provide instruction geared to the needs and pace of each individual student, and we must provide programmed material which takes full advantage of this flexibility. I believe that in an optimally arranged program in some circumstances there might be a ratio of as high as 20 to 1 between the number of right answer frames seen by the poor student and the number seen by the student who missed no questions. In cases where the questions and subsequences were used to select out students who needed remedial instruction in some aspect of the subject or in some prerequisite for the subject, the ratio might run quite a bit higher, of course. Even on material that was completely new to all students, we might see situations in which some students might require twenty times as many steps as the brightest student.

The automatic utilization of the student's response to redirect the program dictates the use of the multiple-choice response mode in any presently practical device. A constructed response, as when the student writes the answer to a question in the program, cannot be utilized simply and directly to control what material the student sees next. The multiple-choice response mode can, as we have just seen, and it is for this purely practical reason that I have preferred the multiple-choice format. There has been some objection to this format on theoretical grounds, but the research of the last year and a half has shown decisively that these objections are invalid, and resulted from a naive confounding of ideas appropriate to research with lower animals and research into the more complex types of mental behavior characteristic of human beings.

One of the questions most often raised about programmed instruction concerns the kind of material that it can usefully handle. I mentioned earlier that the particular technique I have been discussing originated in attempting to solve a training problem involving complex problem-solving. In general, we find that the subject matter best adapted to programming is that hav-

ing a coherent, logical basis or structure which can be systematically developed step by step. For this reason the mathematical and scientific subjects are peculiarly amenable to programming. The kind of courses that are not amenable to programming are the survey courses consisting of many isolated facts, or the purely rote aspects of a subject. The criterion for whether a particular topic is programmable (in the branching technique) is whether there is anything that can be usefully said to a student who has made an error. If we can say to the student who has erred:

(a) your answer is wrong;
(b) this is *what* is wrong with your answer;
(c) this is *why* this feature of your answer is wrong;
(d) this is *how* you go about figuring out what the right answer is; and
(e) now go back and try again,

then we are dealing with programmable material. If the material is such that there is no process of reasoning or employing of related information that will guide the student to the right answer, i.e. if the material is purely rote material, then the branching technique as discussed here is over-elaborate.

I would like to emphasize strongly the point that teaching machines were not conceived as drill masters or as a means of conveniently handling the routine work while the live teacher supplies the ideas. Rather, it is one of the most important aspects of programmed instruction that it can lead the student through a much more careful and rigorous development of the logical heart of a subject than can realistically be attempted in the group teaching situation. The characteristics of the technique are such that it must place emphasis on principles rather than on isolated facts, and it seems to me that this is all to the good.

To a very large extent the question of what can be programmed depends on the skill, ingenuity, and subject-matter knowledge of the programmer. I had always used appreciation of English literature as an example of material that I would not expect to be amenable to programming. This was due purely to my ignorance of how to teach English literature, apparently, because I have just received a manuscript on understanding modern poetry which I consider the best piece of programming I have ever seen. It will appear in our TutorText* series next spring. This incident serves very nicely to make the point that programming is not a routine process, susceptible of detailed analysis and specification, but is basically a creative activity, just as is any other form of communication. It is perfectly possible to write very dull, prosaic, uninteresting programs, and it is also possible to write lively, literate, and interesting programs. A good part of the effectiveness of any program will depend on these relatively elusive qualitative aspects of the programmers' skill.

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* Trademark

In response to the questions Dr. Edwards has raised about the applicability of programmed instruction to groups of different ability levels, I believe that it is obvious that the technique I have been discussing starts with the recognition that students differ as the fundamental problem in the development of teaching techniques. If it were not for the problem of individual differences there would not be a wide requirement for individualized methods of instruction. The primary object of the branching technique is to automatically provide material adapted to the student's manifest needs. On the basis of our present experience, we have no reason to believe that the new techniques are not applicable over the range of abilities ordinarily encountered in public schools. It is inevitable that the initial application of these new techniques will be in those areas in which individualized instruction is most needed. These areas are obviously remedial instruction and advanced instruction, i.e. the extremes of the group, for which the class situation is most unsatisfactory. The most dramatic effect that I hope to see would result from providing practical means for the acceleration of the gifted student.

The question is often raised as to whether programmed instruction will result in turning out students all at the same level of competency. I do not believe that, in the large, this will be the case. We know with our present programs that very dramatic time differences appear between fast and slow students, and with more refined programs, employing a higher degree of branching, differential results attributable to differences in student abilities will become more striking. We will be able to specify with greater certainty than at present what minimum level our slower students will achieve, and perhaps set more realistic goals for the slower students. Our brighter students should be able to advance at a greater relative rate than is now the case.

I have not responded here directly to all of the points raised in Dr. Edwards' paper, but I believe that the discussion of the technique and the philosophy on which it is based should suggest the answers to most of the points raised. I would like to close with one point related to the economics of the situation. While there are many practical problems to be worked out in educational economics, there is one fundamental fact that we must not lose sight of. This fundamental fact is that the basic educational resource that cannot be increased by any administrative procedure, and which must be conserved at the expense of other aspects of the system if necessary, is the learning time available to the individual student. We must use the student's time efficiently. Our society is generating information and requiring the learning of this new information at a rapidly accelerating rate. In the long run, we will find that any method of instruction that does not keep a student working and learning at the maximum practical rate for that student is more expensive in terms of the fundamental resource, student time, than we can afford.

The Panel Discussion

The final session of the Conference was a panel discussion. The panel consisted of Dr. Kenneth Rockwell, Assistant Professor of English, The University of Kansas; Dr. Herbert Bruning, Director of Curriculum, Shawnee-Mission Public Schools; Mr. Norman Crowder, U.S. Industries, the principal speaker for the Conference; and Mr. Robert Johnson, a representative of Encylopaedia Britannica, one of the commercial firms currently programming and distributing learning materials.

In his opening remarks, Dr. Rothwell pointed to the fact that this Conference has drawn attendants with a variety of interests in subject matter and background. This underscores, in part, the significance attaching to a new area such as programmed learning. For himself, Dr. Rothwell stated that his own interest in educational research has been quite recent and attaches mainly to the utilization of programs in English. The English department at The University of Kansas has been attempting to develop instruction in rhetoric, proceeding from the simple elements to the more abstract. In certain ways, programming helps to meet the needs of such a course and is coincidental with the approach used.

The problems of teaching English in a university have forced teachers in the direction of use of automated teaching, Dr. Rothwell believes. Many of the limitations of using this approach in a field such as English are as yet unknown, but neither have the possibilities yet been explored. As a classroom teacher, he has found certain applications of programming applicable to his own teaching. He illustrated this with the possibilities inherent in *English 2600,* a program using a linear approach. Dr. Rothwell believes this approach is causing academic personnel to become aware of programming and machine teaching at the remedial and elementary course level. As yet, no one knows how far in the English program such applicability might be extended. Some research at The University of Kansas has been conducted with poetic form, a hint that such programming may be more widely applicable than currently conceived by many persons. Though no lodestone, programmed learning deserves exploration, Dr. Rothwell believes.

Currently, the theoretician and practitioner seem to be in different camps in their approach to learning situations. Dr. Rothwell stated he believed programmed learning has possibilities of bringing the two together. It is possible that such a joint endeavor will lead to significant improvements in learning situations and increments in the effects of learning.

At this point, Dr. Rothwell raised a question concerning writing of programs. Basically, he asked about the energies and limits of writing. Do students using programs catch up with writers, so that the writers find themselves going furiously to stay ahead? Mr. Crowder answered this question affirmatively. He pointed out that it usually takes from 100 to 150 hours to program adequately the material to be covered in a one-hour lecture. By the

time material to be used is decided upon, selected, written, criticized, and re-written, this much time will be consumed.

Dr. Bruning commented, at this point, that to him programmed learning helps to accomplish what we have always thought the good teacher does. He raised the question as to who does the programming, or who should. Is programming the responsibility of trained personnel, subject-matter experts, classroom teachers? Since it is possible that there should be levels of programming, what is the best procedure? In addition, Dr. Bruning raised the question of whether or not a danger exists in losing creativity and individuality if programmed learning is used in the classroom. As a final question, he asked if machine teaching may be effective for attitudes and concepts. If so, who determines what attitudes and concepts will be developed and who will program them?

Who Will Program?

Mr. Johnson replied first to the general question of who will do the programming. He stated that the Encyclopaedia Britannica programs are designed and compiled by five to seven subject-matter experts with coordination by psychologists trained in learning theory. The latter personnel function to keep the subject matter specialist within the appropriate grade level with the consequent learning characteristics of the group with whom the program is to be used. As to the possibilities of programming on the local level, Mr. Johnson feels it is almost impossible for a local school system to program specific subjects. Availability of personnel and time necessary to program adequately seem crucial elements in answering this question.

Dr. Rothwell interposed at this point that he felt questions of this kind are significant. The machine represents a technological concept while the programs are scientific ones. This illustrates his earlier point about the dichotomy of theoretician and technician. Perhaps this is illustrated in the question asked and the answer to it.

Mr. Crowder agreed that the question of who should program is a crucial one. From the practical standpoint, good programmers are hard to find. He pointed out three essentials in a writer. First, in his work at Western Design, he had little success with subject-matter experts, largely because they did not write well. He pointed out that accompanying this essential element is the fact that the programmer must be able to pursue his task of writing persistently throughout the work day. This, in itself, is foreign to most persons. From personal experience, he has found that many persons with ambitions to write programs lack the elementary writing skills. In certain ways, these are "tricks" but they are still necessary. It is true that these skills may be learned by one wishing to be a program writer. A second element is that the writer must have a command of the material and be able to organize. These first two elements are necessary but not sufficient. The third element Mr. Crowder expressed in this way: The person who wants to be a

program writer must show evidence of once having understood something. In effect, then, he must be able to pursue something until it is understood. This makes it possible for the programmer to recognize something written when it *is* understandable. The program writer must be able to realize whether the question asked in the program follows from the learning material presented.

Mr. Crowder feels there is probably no straightforward answer as to who will program materials, or who should program. The very practical expedient of time probably prevents the local school system from doing so.

Teaching Attitudes and Concepts

Mr. Crowder also replied to the question of teaching attitudes and concepts raised by Dr. Bruning. Concept teaching can probably be handled with relative ease by program writers. The formation and change of attitudes will not be so easily handled. Mr. Crowder stated that the development of attitudes probably is not an adequate area for machined programs to enter.

A statement was made from the floor that a time ratio of 100 hours in programming to one hour of lecture is not so heavy an investment as it sounds. Other media used in education take greater investments, including films. Mr. Crowder agreed with this and made a further comparison: The cost of programming for machines is approximately $2000 per hour while for films it is about $2000 per minute. The costs, monetarily and in terms of time, must be considered in reference to a mass audience. Since there is room in the market for many and varied programs, school personnel should be able to choose adequately and without limitations.

The Classroom Using Programmed Materials

A request was made from the floor for a description of how a classroom would look, using programmed learning for an hour. Mr. Johnson stated that each student would have his own program. In the Encyclopaedia Britannica programs currently available, the student replies to every frame but this response is not always written. When a response is made, the student slides the frame and is given immediate reinforcement. Meanwhile, the teacher is in the classroom and works with the top or bottom levels of the class. If a student has difficulty in answering frames, the teacher works individually with him. If some student gets too far ahead of the class, the teacher makes adaptations for him using other activities.

The Costs of Programmed Materials

Cost per pupil for machines and programs was then asked from the audience. Mr. Johnson said that the cost of a complete Algebra I program from EBF is $14.50 per student. This is representative, but costs do vary somewhat from course to course. Mr. Crowder said the price of the machine

produced by Western Design is $1250. The life expectancy of a machine is not known. Volume of sales will, of course, determine the cost. The materials used in such a machine, if put in book form, will cost from $15 to $20. In film form, as used in the machines, the cost of a program is somewhat less.

Can Students Cheat?

The question was then raised from the floor concerning student procedures used in non-machine programmed learning. Some observers have stated that students will look ahead to answers rather than responding in the accepted fashion. In this case, the student does not become personally involved in the learning and does not work out the answer. If true, this would make such an approach less valuable than using a machine. Mr. Johnson replied that this is a behavior possible with the type of program used by EBF. With such a procedure, the learner must be self-disciplining. However, the learning procedure is followed by a test, and students using such a short-cut method will not perform well on the test. The teacher notes such a discrepancy, follows up in a private conversation with the student, and counsels him about the proper procedure. In this event, the student may repeat the program as homework and thereby catch up.

This led to a question about the use of examinations with programmed materials. Mr. Johnson said that, in the Roanoke study, Educational Testing Service and World Book Company were responsible for testing and validation of learning materials used. In Roanoke, three kinds of presentation were used: (1) Students used programmed materials and the teacher did not assist them in any way, simply taking roll call; (2) students used programmed materials and were assisted by teachers when needed; and (3) conventional teaching procedures were used, with the teacher aware that they were in direct competition with programmed learning. The results indicated only negligible differences in learning gains between the methods. However, in the second condition described above, only 8% of the students failed the test while under conventional procedures, there was a 17% failure rate. The conclusion has been drawn that programmed learning, with teacher assistance, will significantly decrease the failure rate. The tests used to obtain these results were teacher-made, for intermediate measures during learning, and standardized tests at the conclusion of learning.

Mr. Crowder commented that in the machine technique used by U.S. Industries, a test sequence will occur after, say, 50 correct responses. Some four questions might be used in the test sequence. If two errors are made in this sequence, the student will begin the relevant block again. If one error is made, another chance is given, using the branching technique. If he misses all four questions, the program will probably be repeated in its entirety. Of course, if no errors are made, the student proceeds to the next phase or the next program.

There is a question relevant to revisions in programs in the future and the cost to a school system when this occurs. A member of the audience raised this question, and Mr. Johnson pointed out the extent of the revision will determine cost of replacement.

Accreditation of Programmed Materials

In reply to a question concerning accreditation of courses by State departments when programmed learning is used, Mr. Johnson stated that thus far Kansas has not accredited such courses. Some consideration must be given to this by school systems and the state. Mr. Bruning pointed out that this is a serious question but not overwhelming.

Programming Non-Verbal Material

The use of non-verbal concepts and programming for them was asked by a member of the audience. Mr. Crowder said that, currently, machines and programs are limited to symbolic and verbal materials. In the Mark I machine made by Western Design, motion-picture sequences can be shown and this might get at the problem in certain ways. For example, currently a program is being designed for remedial reading and it is obvious to the writers that some provision must be made for audio. Adaptations of this sort will be built into machines and programs as the need occurs, probably.

The Persistence of Motivation

Dr. Scannell, as moderator, pointed out that thus far the longest study on interest reported during the Conference was the use of a program for six hours a day for six weeks. In addition, this study (reported by Mr. Crowder) was with adults. Since children often lose interest in toys and gimmicks of rather intense immediate appeal, what will be the effects of machine teaching on interests over the years? Mr. Johnson replied that in Roanoke the same students were studied over a two year period. It appears that interest in the technique is still quite high for students who have been in the program continuously.

Transfer and Creativity

A final question raised from the floor dealt with transfer and creativity. Since a crucial element in learning is application to other areas and since transfer is facilitated by application and use, what planning and evidence are available about the effect of programmed learning? In addition, has there been attention as yet to creativity? Both Mr. Crowder and Mr. Johnson stated that at this time they do not know of evidence bearing on these questions. Mr. Crowder stated that he is not unaware of the problem and feels that it is met in certain ways by the Tutor Text.

—Reported by Allen Jack Edwards, The University of Kansas

Appendix

A Sample Program

by

Norman A. Crowder

page 3-A

BEGIN HERE

You do not read this sample as you do the rest of the book, going from this page to the next page. Rather, on each page you will be told which page you should read next. Furthermore, each page is divided into two parts, A and B, which are not read at the same time.

While reading this sample, you should use only the page numbers given at the outside edge of each page. (The page numbers for odd-numbered pages will be on the right-hand side of the page; for even-numbered pages, the number will appear on the left-hand side.)

You are now on Page 3-A. Please turn to Page 5-A to begin this sample sequence.

page 3-B

YOUR ANSWER: $m^2+m=m(m+1)$

You are correct, of course.

Very well, we have worked our original problem down from showing that n^2-1 is divisible by 8, n being an odd integer, to showing that $m(m+1)$ is divisible by 2, where m is any integer, either even or odd.

The convenient leverage we have on this problem is that an integer *must* be either even or odd. Now, if m is an even integer, is the number $m(m+1)$ even? That is, is the number $m(m+1)$ divisible by 2?

No	Page 5-B
Yes	Page 12-B
Not necessarily	Page 15-B

page 4-A

YOUR ANSWER: 3.96 is an integer

No, 3.96 is a decimal fraction. The .96 means $\frac{96}{100}$. An integer is a whole number, with no fractional part. 27 is an integer, $\frac{27}{8}$ is not.

Now return to Page 10-A and try again.

page 4-B

YOUR ANSWER: I don't know how to square (2m+1).

To square an algebraic expression having two terms, proceed as follows: Multiply the first term by itself; multiply the second term by twice the first term; multiply the last term by itself, and add the products. For example,

$$(a+b)^2=a^2+2ab+b^2$$

In the example above, the first term, a, is multiplied by itself to give a^2; the second term, b, is multiplied by twice the first term to give 2ab; and the last term is multiplied by itself to give b^2.

What is the square of (3x+2)?

$(3x+2)^2=3x^2+12x+4$	Page 7-B
$(3x+2)^2=9x^2+12x+4$	Page 11-B
$(3x+2)^2=9x^2+6x+4$	Page 13-B
How do you multiply 3x by itself?	Page 14-B

page 5-A

A Theorem in Number Theory

By
NORMAN A. CROWDER

In this sample we shall prove a curious little theorem about the divisibility of certain numbers. Before we begin, however, let's get our terminology set. When we say that 24 is divisible by 6, we mean, of course, that dividing 24 by 6 *leaves no remainder.* In the same way we would say that 29 is *not* divisible by 8, since dividing 29 by 8 leaves a remainder of 5.

Now here is a question on what you have just read. Pick what you think is the right answer to the question and turn to the page number given with that answer. The question is: As we have been using the word "divisible" is 11 divisible by 4?

Yes	Page 7-A
No	Page 10-A

page 5-B

YOUR ANSWER: If m is an even integer, the quantity $m(m+1)$ is not even.

You must have been thrown off by the fact that if m is even, $m+1$ is odd. But the product of an even number and an odd number is even, isn't it?

Now return to page 3-B and try again.

page 6-A

YOUR ANSWER: $\frac{1}{3}$ is an integer

You have it backwards. Integers are whole numbers with no fractional part. For example, 27 is an integer; $\frac{27}{8}$ is not.

Now return to page 10-A and try again.

page 6-B

YOUR ANSWER: $m^2+m=m(m+0)$

In factoring an m out of each term in the expression m^2+m, you're dividing each term by m. When you divide m by itself, you don't get 0 for a quotient, do you? You get 1.

Any factorization can always be checked by multiplying the factors together again to see if you come out where you started. If you multiply $m+0$ by m, you don't get m^2+m, do you?

Now return to Page 15-A and choose a better answer.

page 7-A

YOUR ANSWER: 11 is divisible by 4

We were using "divisible" to mean "divisible without remainder." Dividing 11 by 4 leaves a remainder of 3, i.e. 4 "goes into" 11 twice, with 3 left over. So we would not say that 11 is divisible by 4. Now return to Page 5-A and try the problem again.

page 7-B

YOUR ANSWER: $(3x+2)^2=3x^2+12+4$

You did fine except for one little detail. When you squared the term 3x you squared the x, but not the 3. In general, if you have a term which is itself a product, such as ab, the square of that term is the product of the squares of its factors, i.e.

$$(ab)^2=a^2b^2.$$

If one of the factors is a numeral and the other a literal number, as 4z for example, you would proceed as follows:

$$(4z)^2=(4)^2(z)^2=16z^2$$

Now you should be able to return to Page 4-B and square the term 3x correctly.

page 8-A

YOUR ANSWER: 37 is an integer

You are correct. 37 is a whole number. The other choices offered were fractions, and therefore not integers.

Very well, the theorem we wish to prove is that if n is an odd integer, the number (n^2-1) is divisible by 8. For example, if $n=3$, $(n^2-1)=(3\times3)-1=9-1=8$, which is obviously divisible by 8. If $n=7$, $(n^2-1)=(7\times7)-1=49-1=48$, which is, again, obviously divisible by 8.

Does our theorem say that (n^2-1) is divisible by 8 if $n=6$?

Yes	Page 11-A
No	Page 13-A

page 8-B

YOUR ANSWER: Yes, we have proven our theorem.

I'm afraid we're not done yet. We have proven that if $n=2m+1$, m being any integer, then n is odd and we are trying to prove that n^2-1 is divisible by 8. We have shown that this is equivalent to proving that $m(m+1)$ is divisible by 2. We have proven that $m(m+1)$ is divisible by 2 if m is an even number. But we still have to consider the possibility that m is an odd number, don't we?

Now return to page 12-B and choose another answer.

page 9-A

YOUR ANSWER: If m is any integer, even or odd, the integer $n=2m+1$ must be odd.

You are correct. 2m is always even, so 2m+1 must be odd.

Very well, the problem of showing that if n is odd (n^2-1) is divisible by 8 reduces to showing that $(2m+1)^2-1$ is divisible by 8 whether m is even or odd, since we can write any odd number, n, in the form (2m+1).

There are no 8's showing in $(2m+1)^2-1$ at present. Let's square the quantity in parentheses, clean things up a bit, and see if that shows us where to go next. Which equation below is correct?

$(2m+1)^2-1=4m^2+4m+1$	Page 12-A
$(2m+1)^2-1=4m^2+4m$	Page 15-A
I don't know how to square (2m+1).	Page 4-B

page 9-B

YOUR ANSWER: If m is odd, m+1 is odd.

Come, come, now. If we have any odd number and add 1 to it we'll get an even number, won't we?

Now return to Page 10-B and try again.

page 10-A

YOUR ANSWER: 11 is not divisible by 4

You are correct. 4 "goes into" 11, twice, leaving a remainder of 3. Since there is a remainder, we would not say that 11 is divisible by 4.

In our proof we will want to emphasize that certain numbers are *whole numbers,* i.e. not fractions. The set of whole numbers (including 0 and the negative whole numbers) is called the set of *integers.*

Which of the following numbers is an integer?

3.96	Page 4-A
$\frac{1}{3}$	Page 6-A
37	Page 8-A

page 10-B

YOUR ANSWER: No, we have not yet proven our theorem.

You are correct. We have shown that the problem of showing that n^2-1 is divisible by 8 reduces to showing that $m(m+1)$ is divisible by 2, where $n=2m+1$. We showed that $m(m+1)$ is divisible by 2 if m is even. But we need also to consider the case if m is odd. But consider, if m is odd, is $m+1$ odd or even?

Odd	Page 9-B
Even	Page 16-B

page 11-A

YOUR ANSWER: Our theorem says (n^2-1) is divisible by 8, if $n=6$.

You missed something. Our theorem is concerned only with the odd integers (1, 3, 5, 7, 9, . . . etc.). The even integers (2, 4, 6, 8, 10, . . . etc.) are not covered by the theorem we wish to prove.

Now return to Page 8-A and choose the right answer.

page 11-B

YOUR ANSWER: $(3x+2)^2=9x^2+12x+4$

You are correct. Very good.

$$(3x+2)^2=(3x)^2+(2)(3x)(2)+(2)^2$$
$$=9x^2+12x+4$$

Very well, you should have no trouble now squaring $(2m+1)$. Return to Page 9-A and go on from there.

page 12-A

YOUR ANSWER: $(2m+1)^2-1=4m^2+4m+1$.

You squared $(2m+1)$ very nicely, but you forgot to subtract the 1.

$$(2m+1)^2-1=(4m^2+4m+1)-1$$
$$=4m^2+4m+1-1$$

Now tidy up the expression above and then go back and choose the right answer on page 9-A.

page 12-B

YOUR ANSWER: If m is an even integer, $m(m+1)$ is divisible by 2.

You are correct. If m is even, it can be written in the form $m=2p$, where p is any integer, either even or odd, and therefore

$$m(m+1)=2p(2p+1)$$

which is clearly divisible by 2.

We have seen that if n is an odd integer, $n^2-1=4m^2+4m$, where m is either even or odd. We say that if we could show that $4m^2+4m$ was divisible by 8, we would have proven that n^2-1 is divisible by 8. Since $4m^2+4m$ is divisible by 4, it is sufficient to show that m^2+m is divisible by 2. We considered the case where m was even, and showed that if m is even, $m(m+1)$ is divisible by 2; thus $4m(m+1)=4m^2+4m$ is divisible by 8, and therefore n^2-1 is divisible by 8. Does this prove our original assertion that n^2-1 is divisible by 8?

Yes	Page 8-B
No	Page 10-B

page 13-A

YOUR ANSWER: No, our theorem does not say that (n^2-1) is divisible by 8 if $n=6$.

You are correct. The theorem says that if n is an *odd* number, then the number (n^2-1) is divisible by 8. But it says nothing about what happens if n is an even number, such as 6.

The proof of our theorem depends on n being an odd number, so first we will try to express the fact that n is odd. If the number m is *any* integer, even or odd, which expression below says that n must be odd?

$n=2m+1$	Page 9-A
$n=2m$	Page 14-A
$n=m+1$	Page 16-A

page 13-B

YOUR ANSWER: $(3x+2)^2=9x^2+6x+4$

Tut. You forgot to multiply the second term (the 2) by *twice* the first term (the 3x). Now return to Page 4-B and try again.

page 14-A

YOUR ANSWER: If m is any integer, 2m is an odd integer.

No matter what number m is, the number 2m must be even, since it contains the factor 2. So the number 2m is always an even number, not an odd number.

But you now have some purchase on the right answer. You know now how to write a number that is always even. What can you do to an even number to get an odd number? Return to page 13-A now and choose the right answer.

page 14-B

YOUR ANSWER: How do you multiply 3x by itself?

In general, if you have a term which is itself a product, such as ab, then the square of that term is the product of the squares of its factors, i.e.,

$$(ab)^2=a^2b^2$$

If one of the factors is expressed as a numeral and the other is a literal number, as in the case of the term 4z, for example, you square the numerical factor and multiply the result by the square of the literal factor. For example,

$$(4z)^2=(4)^2(z)^2=16z^2$$

Now you should have no trouble squaring the term 3x. Return to page 4-B and try again.

page 15-A

YOUR ANSWER: $(2m+1)^2-1=4m^2+4m$.

You are correct. Well, we have made some progress. We wanted to show that if n is an odd integer, the quantity n^2-1 is divisible by 8. We expressed the fact that n was odd by writing it in the form $n=2m+1$. We now find that, with substitution, the problem of showing that n^2-1 is divisible by 8, n being odd, is the same as showing that $4m^2+4m$ is divisible by 8, where m may be either odd or even.

The number $4m^2+4m$ cannot be directly shown to be divisible by 8, but it is clearly divisible by 4:

$$\frac{4m^2+4m}{4}=m^2+m$$

If we can now show that m^2+m is divisible by 2, we will have shown that $4m^2+4m$ is divisible by 8, and therefore that n^2-1 is divisible by 8. The expression m^2+m may be easier to work with if we factor it. Which equation below is correct?

$m^2+m=m(m+1)$ Page 3-B
$m^2+m=m(m+0)$ Page 6-B

page 15-B

YOUR ANSWER: If m is an even integer, the quantity $m(m+1)$ is not necessarily even.

Yes it is. You must have been thrown off by the fact that if m is even, $m+1$ must be odd. But the product of an even number and an odd number is even isn't it? Now return to page 3-B and try again.

page 16-A

YOUR ANSWER: If m is any integer, $m=1$ is an odd integer.

I'm afraid not. If m is even, say $m=4$, then $m+1=4+1=5$, which is odd. But if m itself is odd, say $m=7$, then $m+1=7+1=8$, which is even.

Now return to Page 13-A and try again.

page 16-B

YOUR ANSWER: If m is odd, $m+1$ is even.

You are correct. Therefore, the quantity $m(m+1)$ is even whether m is even or odd.

This completes our proof. We wanted to show that if n is an odd integer, n^2-1 is divisible by 8. To prove this, we observed that if n is odd, we can write it in the form $n=2m+1$, where m is any integer, even or odd. We can then say that

$$n^2-1=(2m+1)^2-1$$
$$n^2-1=4m^2+4m=4(m^2+m)$$
$$n^2-1=4m(m+1)$$

The expression on the right is clearly divisible by 4. But $m(m+1)$ is also divisible by 2, since either m or $(m+1)$ is even, and thus $4m(m+1)$ is divisible by 8, as we were required to show.

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Vol. 3, No. 1, *A Summary Report to the North Central High Schools of Kansas on Criterion 2: Pupil Activity Program, Library Service, Guidance Service,* by Kenneth E. Anderson. January, 1952, 24 p.

Vol. 3, No. 3, *A Summary Report to the North Central High Schools of Kansas on Criterion 5: School Plant and Equipment,* by Kenneth E. Anderson, with an addendum: "Acoustical Considerations of School Buildings," by James E. Nickerson. April, 1953, 24 p.

Vol. 4, No. 1, *A Summary Report to the North Central Schools of Kansas on Criterion 3: School Staff,* by Herbert A. Smith and Kenneth E. Anderson. April, 1954, 24 p.

Vol. 4, No. 2, *Body Measurements of Male Students Entering the University of Kansas,* by Edwin R. Elbel. May, 1954, 24 p.

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Vol. 9, No. 1, *Let's Look at the Record! The High School Preparation of 1124 University of Kansas Freshmen,* by George B. Smith. September, 1958, 71 p.

Vol. 9 No. 2, *A Study of Persistence in College Attendance in Relation to Placement-Test Scores and Grade-Point Averages,* by Milo Stucky and Kenneth E. Anderson. April, 1959, 58 p.

Vol. 10, No. 1, *Teaching Reading in the High School in the Language Arts, Social Studies, Science, Mathematics, and Industrial Arts,* by Cloy S. Hobson and Oscar M. Haugh. February, 1960, 46 p.

Vol. 10, No. 2, *A Study of Questionnaire Responses from Kansas High School Participants and Non-Participants in the National Merit Scholarship Testing Program,* by A. W. Dirks and Kenneth E. Anderson. April, 1960, 28 p.

Vol. 11, No. 1, *A Study of the Relationships Between Grade-Point Averages, Placement-Test Scores, Semester Hours Earned, and Area of Major Interest, for the Group Who Entered The University of Kansas in the Fall of 1954,* by E. L. Barnhart and Kenneth E. Anderson. January, 1961, 36 p.

Vol. 11, No. 2, *The University of Kansas Conference on Programmed Learning.* June, 1961, 48 p.